CAPTURE-RECAPTURE STUDIES WITH *ANOPHELES MACULATUS* THEOBALD (DIPTERA: CULICIDAE) THE VECTOR OF MALARIA IN PENINSULAR MALAYSIA

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Abstract. Mark-release-recapture experiments were undertaken in January 1989, in Pos Betau, Pahang, Malaysia, with the malaria vector *Anopheles maculatus*. On two consecutive nights, 121 and 175 blood-fed mosquitos were released. A mean recapture rate of 11.5% and survival rates of 0.699-0.705 with an estimated oviposition cycle period of 2.35 days were obtained from the releases. About 68% of all recaptures were taken within a distance of 0.5 km from their release points and the longest detected flight was 1.6 km. No heterogeneity was found between indoor and outdoor biters of *An. maculatus*.

INTRODUCTION

Anopheles (Cellia) maculatus s.l. Theobald, 1901, displays a wide range of variability in morphological, behavioral and genetic characters. Recently it has been shown that it is a complex of 6 biological species (Green *et al,* 1985; Rattanarithikul and Green, 1986), of which *An. maculatus* sensu stricto is the only member that is present in Peninsular Malaysia where it plays a major role in the transmission of human malaria.

Mosquito species in which different genotypes demonstrate different behavior patterns, such as in their tendency to feed on human or animal blood, and to rest or bite inside or outside of houses, which have obvious relevance to the role of the species in the transmission of disease. In an earlier study, Loong *et al* (1990), reported that there was no evidence to suggest the existence of separate populations of *An. maculatus* s.s. biting different preferred host in their study site in Malaysia. However, there are arguments that there is a possibility of the existence of indoor and outdoor subpopulations in this species. Hence, the present study was conducted to investigate the possible existence of indoor and outdoor genetic varieties of *An. maculatus* s.s. and to obtain information concerning their dispersal and flight range using the mark-release-recapture technique. To date, there are no reports on the dispersal and flight range of *An. maculatus*. In addition the survival rate and oviposition interval of *An. maculatus* were estimated from the recapture data.

MATERIALS AND METHODS

The study took place in an isolated orang asli resettlement area of Pos Betau, Kuala Lipis, Pahang, 140 km north of the city of Kuala Lumpur. The area was previously described by Loong *et al* (1990) and has a high population density of the malaria vector, *An. maculatus*.

The experiments were conducted in January, 1989. Biting female mosquitos were sampled intensively for the first 2 nights between 1900 and 0400 hours using the landing catch method on human bait inside and outside village houses between 1900 and 0400 hours. The mosquitos were collected singly in glass-tubes, identified and released into paper cups. Shortly after capture, the mosquitos were fed on human blood, counted and marked with fluorescent dust blown into the paper cup by an insufflator. They were marked with different colors according to night and location of capture and released just before sunrise between 0500 and 0600 hours at sites R1 and R2 (Figs 1 and 2) on the first and second night, respectively. Unfed, partially fed and weak mosquitos were discarded. The authors have shown in earlier

experiments that the fluorescent dust did not affect the survival rate.

On the third and subsequent nights, recovery of marked mosquitos were carried out daily with collectors stationed indoors and outdoors between 2000 and 0600 hours for 9 days consecutively at catch stations A to I and also at release stations R1 and R2 (Fig 1). In order to determine the dispersal distance of the mosquitos, an additional team of two collectors was stationed in each of the villages as shown in Fig 2.

All captured mosquitos were labeled according to time, catch station and location and were transported to the laboratory in a cooling chamber kept at a temperature of 4-5°C. As pointed out by Loong *et al* (1900), the chamber allows a more accurate estimation of the length of the oviposition cycle. All marked mosquitos were dissected for evidence of recent oviposition and gonotrophic cycle determination. However, a sample of unmarked mosquitos was dissected to determine their physiological age using the Polovodova's

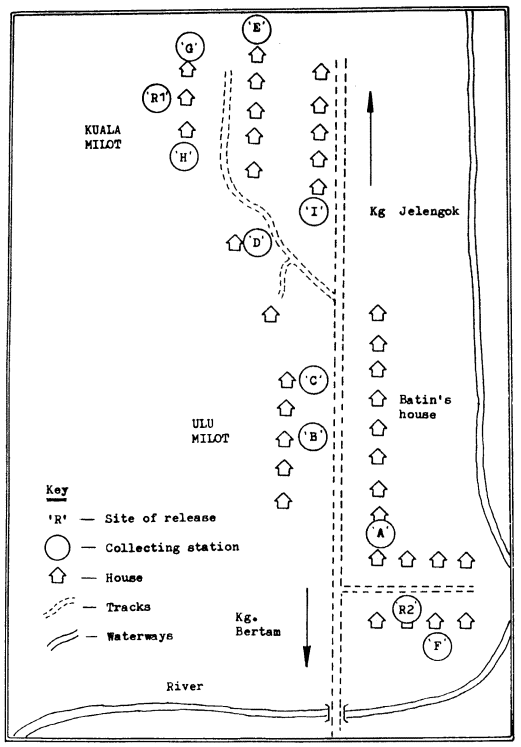

Fig 1—Sketch map of Kampong Kuala Milot and Kg, Ulu Milot, Pos Betau, Pahang, showing collecting stations, A - I.

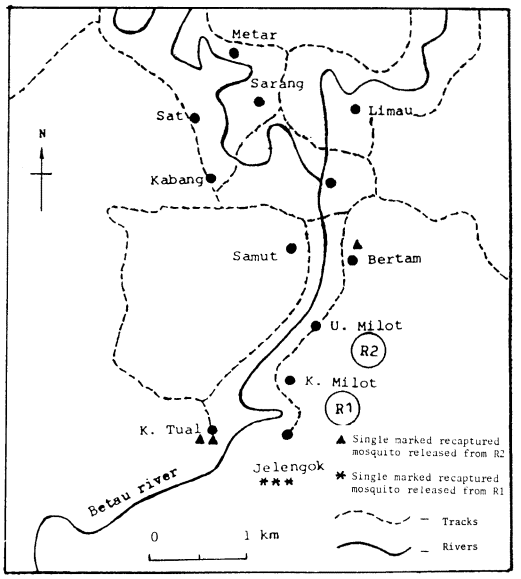

Fig 2—Map of an area in Pos Betau, Pahang, Malaysia showing the villages where recapture teams were stationed.

method of counting the dilatations of the ovarioles (Detinova, 1962).

RESULTS

A total of 296 blood-fed *An. maculatus* were marked and released over two days, with 121 and 175 released on the first and second day, respectively (Table 1). Despite the small numbers released, recapture rates (10.7-12.0%) were relatively high. In the nine nights of recapture, out of 2,148 *An. maculatus* captured, 34 marked were recaptured. Most of them were recaptured between the later half of the second day and early half of the fourth day after release. A majority of these recaptured mosquitos had 'a-sacs'. The estimated oviposition cycle was 2.35 ± 0.45 days (1.98-3.42 days).

Table 2 shows the number recaptured in relation to the distance from the release points. Most of the recaptures were taken close to their release sites. For combined data, 67.6%, 20.6% and 11.8% of the females were recovered in the respective range distance of 0-0.5 km, 0.5-1.0 km and 1.0-1.6 km from the release sites. However, the mean dispersal distance (d) estimated was 0.373 ± 0.467 km (Table 2). The maximum flight range recorded was 1.6 km.

Table 1

Mark-release-recapture data obtained in Pos Betau, Pahang for *An. maculatus.*

Days	Number of mosquitos				
	Captured	Magenta/blue released	Captured	Orange/yellow	Total released
0	152	121	271	175	296
1		1		0	1 (0)
2		1		6	7 (6)
3		5		7	12 (10)
4		5		4	9 (5)
5		1		1	2 (1)
6		0		2	2 (1)
7		0		1	1 (0)
8		0		0	0
9		0		0	0
10		*		*	*
%		10.7		12.0	11.5

Note: The number captured and released are indicated on day 0. An asterisk (*) indicates that sampling was terminated. The percentage sign (%) indicates the proportion of the total released which subsequently recaptured. ( )-Number of mosquitos with 'a-sac' in the ovarioles.

The distribution of captures and recaptures between indoor and outdoor sites is given in Table 3. The X^2 test for heterogeneity was not significant ($p = 0.462$), indicating that there were no discrete indoor and outdoor biting populations of *An. maculatus* in the study area. In terms of endo- and exophagic behavior, *An. maculatus* was found to show an approximate 3 : 1 preference for biting outdoors (Table 3).

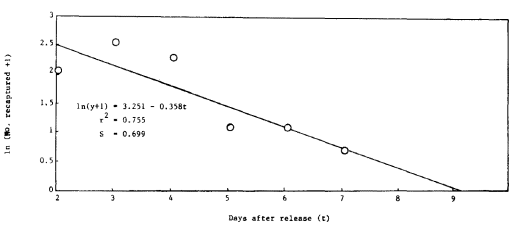

Fig 3—The pooled number of marked *An. maculatus* transformed to ln(n + 1) and plotted as a function of time in days after release (r^2 = coefficient of determination, s = vertical survivorship).

The survivorship of *An. maculatus* during the study period in the area was estimated by two methods. The estimate by regressing the numbers of recaptures transformed into ln (y + 1) as a function of time in days of release was 0.699 (Fig 3). Another independent estimate of daily survivorship derived by regressing the numbers of mosquitos in each group transformed into ln (y + 1) as a function of the duration of the gonotrophic cycles in days was 0.705 (Fig 4). Both estimates agree fairly well.

DISCUSSION

This study reaffirmed the previous report of Loong *et al* (1990) that relatively high recapture rates (11.5%) can be obtained in release experi-

Table 2

Nightly recaptures of marked female *An. maculatus* in relation to distance from the release points.

Distance from release point (m)	Number recaptured
≤ 30	14
60	4
90	1
160	1
500	3
560	1
600	3
650	1
800	2
1,350	3
≥ 1,600	1

- Mean dispersal distance $\bar{d}$ = 372.6 + 467.5 m
- $\bar{d}$ was calculated by the formula,

$$\bar{d} = \frac{\sum_{i=1}^{n} r_i d_i}{\sum_{i=1}^{n} r_i}$$

where r_i = number recaptured at each station (i), d_i = distance in meters of station i from the release point, and n = total number of stations.

ments with *An. maculatus*. However this percentage of recovery is lower than those reported for other malaria vectors *An. culicifacies* (23.9% and 37.5%, (see Curtis and Rawlings, 1980; Rawlings *et al*, 1981), and *An. balabacensis* (16.1%, Hii and Vun, 1985).

The oviposition cycle (2.35 ± 0.45 days) and the survival rates (p = 0.699 − 0.705) estimated for *An. maculatus* in this study were close to that reported by Loong *et al* (1990) (2.30 ± 0.47 days and p = 0.710 − 0.761). The slight delay in oviposition and the lower survivorship could possibly be due to the weather. The number of rainy days recorded was 23 for the month the present study was carried out and only 8 days during the one conducted by Loong *et al* (1990). Presumably the rain curtailed mosquito activity to the extent the oviposition cycle was delayed and survivorship was reduced.

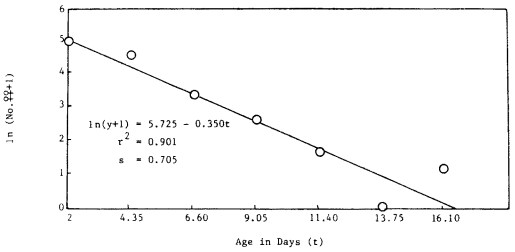

Fig 4—The number of mosquitos in each age group transformed into ln(n + 1) as a function of calender age at 2.35-day gonotrophic cycle.

The study also revealed the remarkable flying ability of *An. maculatus*. The maximum flight range recorded was 1.6 km. This information is epidemiologically important in control programs and for the assessment of any control measures in places where the vector is *An. maculatus*, it is essential for program managers to consider a radius of at least 2 km barrier zone around the area to be assessed in order to prevent the infiltration of mosquitos.

The ratio of outdoor versus indoor collection of *An. maculatus* was found to be 3 : 1 indicating a slight degree of exophagy. The fact that the same *An. maculatus* individuals have been shown to bite both indoor and outdoor (Table 3) and to bite both man and cattle (Loong *et al*, 1990), the absence

Table 3

Recaptures of marked females of *An. maculatus* in the indoor and outdoor of house collections.

First captured	Recaptured		Total mosquitos screened
	Indoor	Outdoor	
Indoor	4	8	524
Outdoor	9	13	1,624

X^2 = 0.646, p = 0.462

of animals (both wild and domestic eg cow) and the semi-nomadic lifestyle of the locals in the area which results in long periods away from their homes during which they sleep in temporary shelters increase significantly the man-mosquito-contact. The tendency for *An. maculatus* to spend the major part of their gonotrophic cycle outside (GL Chiang, unpublished data), the high survival rate and the ability to fly long distance are factors causing *An. maculatus* to act as an efficient vector to transmit malaria in the study area.

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